REMARKS/ARGUMENTS

Favorable reconsideration of this application, as presently amended and in light of the following discussion, is respectfully requested.

Claims 1-5, 9, 11, 12, and 15 are pending in the present application.

Claims 1-5, 9, 11, 12, and 15 were rejected under 35 U.S.C. §103(a) as unpatentable over Nakajima et al. (U.S. Patent Publication No. 2002/0139416, hereinafter Nakajima) in view of Saidov et al. (*Technical Physical Letters*, 27, 2001, pp.319-322, hereinafter Saidov) or Chan et al. (*Materials Letters*, 14, 1992, pp. 263-267, hereinafter Chan); and Claims 1-5, 9, 11, 12, and 15 were rejected under 35 U.S.C. §103(a) as unpatentable over Saidov or Chan in view of Nakajima.

With respect to the rejection of independent Claims 1 and 9, Applicants respectfully traverse the outstanding grounds of rejection. The outstanding Office Action takes the position that Saidov and Chan disclose the claimed polycyrstal and cures deficiencies in Nakajima. To traverse this position, Applicants initially note distinctions between Chan, Saidov, and the claimed invention. Then, Applicants point out specific errors in the outstanding Office Action.

Difference between the claimed invention and each of the references in manufacturing method

Chan discloses a liquid-phase epitaxial growth method in which a single crystal thin-film is formed on a Si (111) single crystalline substrate by epitaxial growth by creating a supersaturation in a solution obtained by dissolving Si and Ge into a solvent containing 60% of gold and 40% of bismuth.

Saidov discloses a liquid-phase epitaxial growth method in which a single crystal thin-film is formed on a Si (111) single crystalline substrate by epitaxial growth by creating a

supersaturation in a solution obtained by dissolving Si and Ge into a solvent containing gallium or tin.

By contrast, the manufacturing method of Claim 9 uses $A_{1-X}B_X$ (in non-limiting embodiments of the claimed invention A is Si and B is Ge; see Claim 11) as the raw material, and does not dissolve these into a solvent but melts these A and B materials, for example, in a crucible without any solvent. Then, for example, the obtained AB melt is moved in one direction in a crystal growth furnace with a temperature gradient to be gradually solidified, and thus bulk crystals of AB are grown, which is called a melt growth method. Particularly, Claim 9 recites "preparing a melt containing multiple elements; and cooling the melt while controlling a cooling rate and/or a composition of the melt to obtain a multi-element polycrystal." The epitaxial growth method to obtain a thin film of crystals and the molten growth method to obtain bulk crystals are entirely different from each other in growing technique.

Difference between the claimed invention and each of references in crystal structure:

The crystals of Chan or Saidov are epitaxially grown from single crystals of a SiGe thin film using a Si (111) single crystalline substrate, and due to the characteristics of the epitaxial growth, the crystals are thin-film single crystals inheriting the orientation of the substrate crystals. The thickness of the thin-film single crystals of Chan is several micrometers to over ten micrometers. Saidov does not explicitly mention the thickness of the thin-film crystals.

By contrast, the crystals of the claimed invention are grown in a melt without using substrate crystals, and therefore they do not take a form of single crystals but they are polycrystalline bulk crystals. Although it may differ depending on the growing conditions, examples of the AB bulk polycrystals will take a form of crystal grains of several millimeters

to several centimeters. For example, when a thin crystal is needed, a piece is sliced from the bulk polycrystals.

With regard to the thin-film single crystals grown by Chan, since it is obtained by growing a very thin film crystal by using the epitaxial growth, there is no dispersion in composition. However, in some cases, there results a slight compositional gradient only in the thickness direction (which is the same as the crystal growing direction) depending on the growing conditions.

With regard to the thin-film single crystals grown by Saidov, since the epitaxial growth is carried out with use of a solution obtained by dissolving Si and Ge into gallium or tine solvent until Si is depleted, a thin-film single crystal having a one-way composition gradient in which the composition of Ge increases in the thickness direction (which is the same as the crystal growing direction) is obtained. The surface of the thin film single crystal is made of pure Ge.

As described above, the thin-film single crystal grown by Chan or Saidov is a SiGe thin-film single crystal having either a uniform composition without a variation in composition ratio, or a composition characterized in that the composition ratio changes in only one direction, which is the thickness direction (the same as the crystal growing direction). As to the composition ratio of Ge, Chan changes the composition ratio of the materials systematically in a range of 0 to 0.20 for each growth, and thus a different crystal composition is obtained for each growth.

By contrast, the bulk polycrystal of the claimed invention can be expressed in a constant average composition of $A_{1-x}B_x$, but the bulk polycrystal is an aggregate of crystals having different compositions. More specifically, the bulk polycrystals of the claimed invention have such a structure in which a different composition of $A_{1-x2}B_{x2}$, $(x1<x<x2)$ is present in local sites that are three dimensionally dispersed in the mother phase of $A_{1-x1}B_{x1}$ of

the AB bulk polycrystals. Thus, the polycrystals of the claimed invention are characterized by having such a structure that a three-dimensionally nonuniform compositional dispersion is introduced. Thus, the crystals of the claimed invention are entirely different from the thin-film single crystal grown by Chan or Saidov in its crystal structure, dispersion state of elements and dispersion state of composition ratio.

Difference between the claimed invention and each of references in distortion within crystal:

Chan uses the Si (111) single crystal as the substrate and forms the SiGe thin-film single crystal by means of the liquid phase epitaxial growth method. During the growth, the composition of the crystal is systematically changed within a range of 0 to 0.20. With regard to samples thus obtained, Chan carried out the photoluminescence measurement to examine the composition dependency of the light emitting energy of the exciton bound to the bismuth impurity taken in the thin film single crystal. From the results obtained, the composition dependency of the band gap of the SiGe thin-film single crystals epitaxially grown on the Si(111) substrate is obtained within a Ge composition range of 0 to 0.20. Further, comparison with the values provided in a document for a strain-free SiGe crystal indicates that the band gap in the SiGe thin film single crystals grown on the Si (111) substrate by the epitaxial growth crystal is smaller than that of the strain-free SiGe crystal having the same crystal composition. From this result, it is concluded that the SiGe thin film single crystal layer epitaxially grown on the Si (111) substrate contains strain and the band gap is lowered due to the strain. Here, the strain occurring in SiGe is due to the difference in lattice constant between the Si single crystalline substrate and the SiGe thin film crystal layer. Since the SiGe thin film single crystal layer is formed on the Si (111) single crystalline substrate by epitaxial growth, and the lattice constant of SiGe is larger than that of Si, it is theoretically concluded that the distortion is of a bi-axial type in which the compressive strain occurs

within the (111) face parallel to the growth direction, and thereby tensile strain occurs within a surface perpendicular to the growth direction.

By contrast, the bulk polycrystal of the claimed invention has a constant average composition that can be expressed by $A_{1-x}B_x$, but has a composition dispersion three dimensionally in which the composition differs from one region to another, which is entirely different from the SiGe thin film crystal epitaxially grown on the Si (111) single crystal layer on the substrate by Chan. More specifically, the claimed invention includes a bulk crystal having such a structure in which regions where the composition expressed by $A_{1-x2}B_{x2}$ ($x1 < x < x2$) differs from one to another are three-dimensionally dispersed within the mother phase $A_{1-x1}B_{x1}$ of the AB bulk polycrystal. As described, the claimed invention is characterized by having a structure in which such a three-dimensionally nonuniform compositional distribution is introduced, and therefore regional distortions are created within the crystal layer as reflecting the nonuniform compositional distribution, and therefore the distortions are three-dimensionally nonuniformly distributed. Thus, the distortion of the claimed invention is essentially different from the distortion of Chan, which is caused by the difference in lattice constant between the Si single crystalline substrate and the SiGe thin film crystal layer, and naturally, the distortion distribution within each crystal is essentially different from that of the reference.

Difference between the claimed invention and each of reference in structure of solar cell:

Saidov proposes a solar cell in which a p-type SiGe thin film single crystal layer is formed by epitaxial growth on an n-type Si single crystal substrate, and a solar cell in which an n-type SiGe thin film single crystal layer and a p-type SiGe thin film single crystalline layer are formed by epitaxial growth on an n-type Si single crystal substrate. In such a solar cell, the composition within the SiGe thin-film single crystals is not constant, but the epitaxial

growth is carried out to have such a one-way compositional gradient in which the composition of Ge increases in the crystal growth direction. The characteristic feature of the thin-film single crystal is that the outermost surface is made of pure Ge. When the epitaxial growth method is employed, it is possible to provide a compositional gradient in the crystal growth direction in the thin film crystal, but it is extremely difficult or practically impossible to provide three dimensional compositional distributions within crystal.

By contrast, the bulk polycrystals of the claimed invention can be expressed in a constant average composition of $A_{1-x}B_x$, and have such a structure in which a different composition of $A_{1-x2}B_{x2}$, (x1 <x<x2) is present in local sites that are three dimensionally dispersed in the mother phase of $A_{1-x1}B_{x1}$ of the AB bulk polycrystals. Thus, the polycrystals of the claimed invention are characterized by having such a structure that a three-dimensionally nonuniform composition dispersion is introduced. The solar cell of the claimed invention includes such a bulk polycrystal substrate whose structure of crystal and compositional distribution are entirely different from those of the reference. This solar cell is entirely different in structure from that proposed by Saidov, which is based on the hetero structure crystals of the SiGe thin film single crystals having a compositional distribution limited in one direction, and epitaxially grown on the Si single crystal substrate.

Turning now to the specific errors in the outstanding Office Action, Applicants respectfully traverse the positions taken in paragraphs 6 and 12 of the outstanding Office Action.

Saidov indicates that the long-wavelength edge of the wavelength at which optical absorption is expressed in the $Si_{1-x}Ge_x$ crystal has a shorter wavelength in the case where x = 0.05 to 0.10 as compared to the case where X = 0.50. From this fact, the outstanding Office Action takes the position that a person of ordinary skill in the art would modify Nakajima on the grounds that a SiGe solar cell having a lower x value is obviously preferable.

However, when the long-wavelength edge of optical absorption has a longer wavelength, a wider wavelength region of solar light spectra can be absorbed, and therefore it becomes possible to increase the current value of the solar cell under illumination of the solar light. Thus, the composition dependency of the long-wavelength side of the optical absorption presented by Saidov merely suggests a possibility of increasing the current value of a solar cell with an increase in the Ge crystal composition.

By contrast, the bulk polycrystals of the claimed invention can be expressed in a constant average composition of $A_{1-x2}B_{x2}$, and have such a structure in which a different composition of $A_{1-x2}B_{x2}$, (xl<x<x2) is present in local sites that are three dimensionally dispersed in the mother phase of $A_{1-x}B_x$ of the AB bulk polycrystals. Thus, the polycrystals of the claimed invention have such a structure that a three-dimensionally nonuniform composition dispersion is introduced therein.

As described above, the composition dependency of the long-wavelength side of the optical absorption presented by Saidov merely suggests a possibility of increasing the current value of a solar cell with an increase in the Ge crystal composition. Thus, unlike the claimed invention, this reference does not use a particular crystal having a three-dimensionally nonuniform composition. Therefore, it is not possible to induce such a result that an average composition x that can maximize the conversion efficiency in a range of $x<0.10$ can be present.

According to the position taken in the outstanding Office Action, Chan discloses that in the $Si_{1-x}Ge_x$ crystal epitaxially grown on the Si (111) single crystal substrate, as the x value is lowered, the band gap is reduced and the distortion is increased as compared to the case where the Ge concentration is high. Based on this disclosure in Chan, the outstanding Office Action has rejected the claimed invention on the grounds that a range of $x < 0.10$ is preferable for solar cells, and it can be easily estimated from the Chan's disclosure.

However, the composition dependency of the band gap presented in Fig. 2 of Chan indicates that the difference in band gap between strained SiGe thin film single crystal and strain-free SiGe crystal becomes larger as Ge fraction(x) increases. This means that as the crystal composition ratio increases in a range of $0 < x < 0.2$, on which Chan carried out the measurements, the strain increases. This disclosure is very rational in consideration of the fact that the difference in lattice constant between the Si single crystal used for the substrate, and SiGe single crystal layer increases. Thus, the results obtained by Chan suggests that when the crystal composition ratio is increased within a range of $0 < x < 0.2$, the long-wavelength edge of the optical absorption is shifted to a longer wavelength, and therefore solar light spectra of a wider range of wavelengths can be absorbed, thereby making it possible to increase the current value of the solar cell.

However, from these results, it is not possible to induce the claimed invention, which is based on the compositional distribution in the bulk polycrystals that can be expressed by $A_{1-x}B_x$ whose an average composition is x and constant, and have such a structure in which a different composition of $A_{1-x2}B_{x2}$, ($x1 < x < x2$) is present in local sites that are three dimensionally dispersed in the mother phase of $A_{1-x1}B_{x1}$ of the AB bulk polycrystals, and the solar cell made of such bulk polycrystals having such a structure that a three-dimensionally nonuniform composition dispersion is introduced therein. It is further impossible to induce from the results of the reference that an average composition x that can maximize the conversion efficiency in a range of $x<0.10$ can be present in such a solar cell. Thus, the claimed invention exhibits such an advantageous effect that can be exhibited for the first time with the crystals having the particular compositional distribution employed in the claimed invention.

The position taken in paragraph 12 of the outstanding Official Action is based on the reasoning that it can be logically induced that the efficiency can be increased when the solar cell of Saidov or Chan is manufactured by the technique of Nakajima.

However, as described above, the structure of the solar cell proposed by Saidov is entirely different from the structure of the claimed invention.

In Saidov, the optical response spectra of the SiGe thin film single crystal layer actually grown on the n-type Si (111) substrate are obtained by measuring the short-circuit current value while a monochromatic light is irradiated while changing the wavelength. However, this reference makes no mention of the evaluations of the performances of the solar cell, that is, the value of the short-circuit current when a white light to simulate the solar light is irradiated, the value of the open-circuit voltage, the value of the conversion efficiency, etc., which are the basic characteristics of solar cell. Further, in the solar cell of Saidov, the SiGe thin film single crystal is a thin film single crystal having a composition gradient in one direction in which the Ge composition ratio increases in the thickness direction (that is, the crystal growth direction), and this references makes no mention of its average composition.

The results obtained by Saidov are based on the structure of the solar cell, which is different from that of the claimed invention, and the basic performance evaluations of the solar cell are not discussed, or the composition of the thin film single crystal is not indicated in this reference. Therefore, it is not possible from these results to induce the techniques of the claimed invention, which is based on the compositional distribution in the bulk polycrystals that can be expressed by $A_{1-x}B_x$ whose an average composition is x and constant, and have such a structure in which a different composition of $A_{1-x2}B_{x2}$, (x1 <x<x2) is present in local sites that are three dimensionally dispersed in the mother phase of $A_{1-x}B_x$ of the AB bulk polycrystals, and the solar cell made of such bulk polycrystals having such a structure that a three-dimensionally nonuniform composition dispersion is introduced therein. It is

further impossible to induce from the results of the reference that an average composition x that can maximize the conversion efficiency in a range of $x<0.10$ can be present in such a solar cell. Thus, the claimed invention exhibits such an advantageous effect that can be exhibited for the first time with the crystals having the particular compositional distribution employed in the invention.

Applicants respectfully traverse the positions taken in paragraph 14 of the outstanding Office Action.

As pointed out by outstanding Official Action, the results obtained in the experiment discussed in the Declaration submitted previously are unexpected. Thus, it is obviously impossible to logically lead to the claimed invention from the disclosures of the cited references.

In accordance with MPEP §716.01(d) and §2144.08, Applicants respectfully request an explanation as to the reasons why the previously submitted evidence of unexpected results were not give substantial weight. Applicants have offered evidence of unexpected results to rebut the Office's position of obviousness, in accordance with the secondary considerations which are part of the Graham factors. Currently, the record does not include an explanation as to why the evidence of secondary considerations was not given substantial weight.

In view of the above-noted distinctions, Applicants respectfully submit that the pending claims patentably distinguish over the cited references.

Consequently, in light of the above discussion and in view of the present amendment, the present application is believed to be in condition for allowance and an early and favorable action to that effect is respectfully requested.

Respectfully submitted,

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